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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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(21) International Application Number: PCT/NZ93/00077 (22) International Filing Date: 31 August 1993 (31.08.93) (30) Priority data: 244152 31 August 1992 (31.08.92) NZ (71) Applicant (for all designated States except US): TRU-TEST LIMITED [NZ/NZ]; 241 Ti Rakau Drive, East Tamaki, Auckland (NZ). (72) Inventors; and (75) Inventors/Applicants (for US only): BOULT, Brian, Frederick [GB/NZ]; 14 Kelly Street, Mt Eden, Auckland (NZ). DINGLEY, Geoffrey, Warren [NZ/NZ]; 12 Zion Road, Birkenhead, Auckland (NZ). HESLIN, Michael, Brett [NZ/NZ]; 24 Ashton Avenue, Mt Eden, Auckland (NZ). RYAN, Kevin [NZ/NZ]; 122 Laingholm Drive, Laingholm, Auckland (NZ). JACKSON, Peter, Swiftsure [NZ/NZ]; 38 Seaview Terrace, Mt Albert, Auckland (NZ).		(74) Agents: BENNETT, Michael, R. et al.; 6th Floor, Huddart Parker Building, Post Office Square, PO Box 949, Wellington 6015 (NZ). (81) Designated States: AT, AU, BB, BG, BR, BY, CA, CH, CZ, DE, DK, ES, FI, GB, HU, JP, KP, KR, KZ, LK, LU, MG, MN, MW, NL, NO, NZ, PL, PT, RO, RU, SD, SE, SK, UA, US, VN, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG). Published With international search report.	
(54) Title: FLUID METER (57) Abstract <p>A meter which measures fluid flow by passing the fluid through a receptacle (2) and determining the mass of fluid in the receptacle. The shape of the receptacle (2), the fluid flow path within the receptacle and the receptacle outlet (21) are chosen to ensure that for a selected fluid the mass of fluid in the receptacle is a linear function of fluid flow rate. The mass is determined by weighing (25) the receptacle (2). Total mass flow is determined by integrating (210) the mass measurement overtime if particular application of the meter is as a milk meter.</p>			

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"FLUID METER"**TECHNICAL FIELD**

5 This invention relates to the measurement of fluid flow rate and/or total mass flow. The invention relates particularly, though not solely to measuring the flow rate and/or total mass flow of milk supplied during milking of cows. In this application the invention provides an electronic milk meter.

By "flow rate" it is meant liquid flow rate in mass per unit time e.g. kg/min. By
10 "total mass flow" it is meant the integration of flow rate over the measurement time.

BACKGROUND ART

When measuring the flow of, in particular, liquids which are not uniform in composition, such as, for example, the milk delivered during machine milking which
15 foams due to substantial and varying amounts of entrained air and other gases, an accurate determination of the flow rate or the total mass flow of liquid is difficult to achieve. With milk, because of the differing quantities of air and other gases contained within the milk, the density of the milk may change substantially during the milking process. An acceptable accuracy for total mass flow is within 2% of the
20 actual yield of milk supplied. It has been found that it is difficult if not impossible to remove the gas from milk to an extent that will enable this accuracy to be achieved whilst measuring the milk volume during milking or very soon after the milking occurs. As one of the main purposes of measuring the total mass flow is to determine the milk yield from each animal substantial removal of gas would require the milk to
25 be retained in individual cow portions for a substantial period of time. Clearly this is impractical. A method proposed to overcome the problem of density variation in measuring milk volume is described in US 5,035,139 where the foam profile of milk passing through a chamber is measured by measuring specific densities of the milk at different heights in the chamber. It would, however, be advantageous to measure total
30 mass flow in a more direct manner rather than by making numerous volume and density measurements.

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DISCLOSURE OF INVENTION

It is therefore an object of the present invention to provide a means of measuring flow rate and/or total mass flow which will simplify the aforementioned measuring procedure or which will at least provide the industry with a useful choice.

5 Accordingly in one aspect the invention consists in apparatus for measuring flow rate of a fluid comprising, a chamber, an inlet to said chamber, an outlet from said chamber, means for determining the mass of fluid in the chamber wherein the shape of said chamber and/or the shape of at least part of the fluid flow path through the chamber is such that the flow rate of a selected fluid through said chamber is in a
10 substantially linear relationship to the mass measured by said means.

In a further aspect the invention consists in apparatus for measuring total mass flow of a fluid comprising apparatus for measuring flow rate according to the preceding paragraph and summation means to determine total mass flow by integrating a plurality of measurements of said flow rate with respect to time.

15 In a still further aspect the invention consists in a method of measuring flow rate of a fluid comprising the steps of weighing a chamber through which fluid flows, said chamber being shaped and/or at least part of the fluid flow path through the chamber being shaped such that the flow rate of a selected fluid is in a substantially linear relationship to the weight of fluid within said chamber.

20 In a still further aspect the invention consists in a method of measuring total mass flow of a fluid comprising measuring flow rate according to the method of the preceding paragraph and integrating a plurality of measurements of said flow rate with respect to time to determine a total mass flow of fluid passed through said chamber.

25

BRIEF DESCRIPTION OF DRAWINGS

Preferred forms of the invention will now be described with reference to the accompanying drawings in which;

Figure 1 is a plan view of the mechanical components of a first form of
30 apparatus for measuring flow rate and/or total mass flow of a fluid,

Figure 2 is a side elevation of the construction of Figure 1,

Figure 3 is a cross section on AA in Figure 2,

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Figure 4 is a cross section on BB in Figure 1,

Figure 5 is a plan view of a distribution plate for use in the apparatus according to any one of Figures 1 to 4,

Figure 6 shows flow rates of a selected fluid through the apparatus shown in
5 Figures 1 to 5 plotted against the weight of fluid in the apparatus as registered by a load cell,

Figures 7 to 9 show three sectional views of a second form of apparatus for measuring flow rate and/or total mass flow of a fluid, and

Figure 10 is a block diagram of the signal processing circuits for the apparatus.

10

MODES FOR CARRYING OUT THE INVENTION

In the measuring apparatus shown in figures 1 to 5 fluid is passed through a chamber 2 which is suspended within a container 20 by a force transducer mechanism 25 which generates a signal which is conditioned to provide a measure of fluid flow
15 rate. The substantially cup shaped chamber 2 receives fluid through the open top of compartment 3 and fluid leaves the chamber through a conduit 4 extending upwardly from the base 5 of the chamber 2. The conduit 4 is open at its lower end 6 and has a longitudinal slot 7 in the wall thereof. In the preferred form the slot 7 is substantially parallel sided, although other shapes of slot, such as a slot widening
20 towards the lower end could be used. Thus fluid being deposited through the entrance 3 will pass through the slot 7 to the outlet 6.

Where the fluid to be measured is milk (for simplicity the term "milk" will be used in this description and the apparatus referred to as a "milk meter") coagulated particles, or the like may be present, the width of the slot 7 must be sufficient to
25 enable such particles to pass through without clogging. A slot 7 having a width of 2mm has been found to be adequate but it is desirable to have a wider slot 7 such as 6mm. Where a slot 7 of this width is to be used it is necessary to impede the passage of the milk through slot 7 and this can be achieved by the use of a baffle 8. Baffle 8 is preferably substantially arcuate in shape and in the embodiment shown in the
30 drawings the arcuate baffle 8 extends a little less than half way around the circumference of the conduit 4. Baffle 8 could alternatively be positioned inside the conduit 4 rather than outside as shown in the drawings. An alternative baffle shape

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to that illustrated which would be suitable is a spiral.

The milk is desirably introduced into the compartment 3 through a distribution plate 10 which is shaped to guide the milk away from the upper end of the conduit 4. This is achieved by providing distribution plate 10 with an annular depression 11 and a plurality of apertures 12 therein (see figure 5) through which the milk may flow. An inlet chamber 14 located above the guide plate receives milk tangentially through an inlet port 15. This allows some cyclonic or rotational movement of the milk to occur which will assist in degassing the milk.

The cup shaped chamber 2 is suspended within an outer housing 20, the upper parts of which may form the inlet chamber 14. Outer housing has an outlet 21 through which milk exiting conduit 4 through outlet at 6 will ultimately pass.

The outer housing 20 carries a force transducer such as diaphragm load cell 25 to which chamber 2 is connected by a suitable connecting member 26. As this is the only means of support for chamber 2 and as the apparatus is used with the longitudinal axis of chamber 2 vertical the weight of milk in the chamber 2 will cause distortion of the diaphragm which causes the load cell strain gauges to vary in resistance which variation is used to vary the load cell output voltage.

Thus the instantaneous weight of milk in the chamber 2 gives rise to an output signal which can be measured. Desirably, the milk flow rate in kilograms per minute is substantially linear with respect to the load cell output. Figure 6 is a graph of load cell output voltage against flow rate of milk for apparatus of the type described. Curve 30 is for the chamber configuration described herein where substantial linearity has been achieved. Curve 31 is for a chamber having two pairs of parallel sides with a rectangular slot in one side. It can be seen such a simple arrangement is non-linear.

Linearity can be achieved by suitably selecting the shape of chamber 2. In the embodiment shown in figures 1 to 5 it can be seen that the container is somewhat egg shaped and in fact a container shape determined by the relationship

$$V(h) = V_{\max} (h/h_{\max})^n$$

where $V(h)$ is the volume of the container for a fluid height h ,

h_{\max} is the maximum height of fluid,

V_{\max} is the volume of fluid at the height h_{\max}

and n is the exponent

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is suitable when $h_{\max} = 90$ mm, $V_{\max} = 314$ cubic cm and $n = 1.74$. Other factors will also have some effect. For example, the positioning and size of the baffle 8, the size and shape of the conduit 4 and the width of the exit slot as a function of height. If a non parallel sided slot 7 is used a different relationship between volume and height would be required.

The output of the load cell is indicative of weight and the linear relationship between flow rate and weight which can be obtained (curve 30) means the milk meter is substantially independent of the milk density. As already mentioned milk has a tendency to foam in transfer and the density of aerated milk is much lower than non-aerated milk. Substantially eliminating density as a factor in the measurement of total mass flow is therefore highly advantageous.

In use milk from a cow, is introduced into the upper chamber 14 through the inlet 15. The milk then falls through apertures 12 in the distribution plate 10 into the chamber 2 to pass between the wall of the conduit 4 and the baffle 8. It then flows through the slot 7 and outwardly down through the conduit 4, into outer housing 20 and then leaves the meter through outlet 21. At any given time a quantity of milk will be present in chamber 2. The flow rate will inevitably cause the quantity of milk within the chamber 2 to vary. The load cell will therefore produce a signal having a varying amplitude. The total mass flow is derived by integrating this signal with respect to time and thus is not dependent on having a constant flow rate.

A second form of milk meter is shown in figures 7 to 9. This uses a chamber having two parallel sides which is thus able to be accommodated within a "flat pack" outer housing 120. In this form of meter the chamber 102 is suspended within outer housing 120 by leaf springs 126. In this form of meter a different transducer is used to provide the output signal, namely a linear variable - differential transformer (LVDT) 125.

Milk enters the meter through inlet 115 and passes into a distribution manifold 114 where it spreads transversely to pass down through the two discharge ports 112. The milk then passes into opposite sides of chamber 102. The flow path followed by the milk is indicated by the arrows marked in each of figures 7, 8 and 9.

On entering chamber 102 from discharge ports 112 the milk flows into sub chambers 103. It passes from these sub chambers around baffles 108 into a further

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sub chamber 104 which is in communication with both sub chambers 103. The milk then exits from sub chamber 104 through an aperture or slot 107 from whence it flows to the bottom of outer container 120 and leaves the meter through outlet 121. The configuration of slot 107 is determined by the same factors as have already been
5 described in relation to the first form of meter. The external shape of chamber 102 together with the flow path determined by ports 112, baffles 108 and sub chamber 104 minimises froth inducement in the milk as it passes through the meter and thus reduces errors in metered output arising from this phenomenon. Furthermore, as for the first form of meter the second form of meter has a configuration such as to
10 ensure that the weight of milk within chamber 102 at any given time is linearly proportional to the flow rate at that time and curve 30 in figure is substantially representative of the performance of the second form of milk meter.

Chamber 102 is suspended within outer housing 120 by two leaf springs 126 cantilevered from mounting member 127 which in turn is fastened to the outer
15 housing 120. A link member 128 connects between the outer ends of springs 126 and is fastened to the back wall 129 of chamber 2. Milk present in chamber 2 causes leaf springs 126 to deflect downward by a distance proportional to the weight of milk in chamber 2. This displacement is measured by an LVDT transducer 125. This comprises mutually coupled transformer windings 130 surrounding a movable
20 ferromagnetic core 131. The core is free to move longitudinally within windings 130 and is mechanically coupled by arm 132 to link member 128. Thus as the leaf springs displace and chamber 102 moves downwards, so does core 131 thereby reducing the mutual inductance between the LVDT windings 130 and thus varying the output voltage of the LVDT.

25 The output of the LVDT is a linear function of the displacement of core 131 and as the displacement of chamber 102 is substantially a linear function of the flow rate of fluid passing through it, the output of the LVDT is a linear function of that flow rate. The LVDT output signal may be integrated to provide a measure of total mass flow.

30 Meter signal processing for deriving and displaying flow rate and total mass flow measurements from the transducer output signal is shown in Figure 10. The signal processing system illustrated could be used for either of the meter input stages

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described above.

The electrical signal 201 from the selected primary transducer is input to analogue signal conditioning circuits 202 where the signal is amplified and noise filtered. As mentioned above secondary transducers may be used to assist in
5 producing a clean and accurate signal and thus the conditioning-circuits 202 may receive more than one input. The output of the signal conditioning circuits is fed to a digitising circuit 203 which samples the instantaneous signal value and converts each sample to a digital input 204 for microprocessor 205. Digitiser 203 is under the control of microprocessor 205.

10 Microprocessor 205 carries out a number of functions determined by the microprocessor software. These include a noise suppression function 206 and a flow rate calculation function 207. Flow rate calculations are successively stored in memory 208 and are available to output to a digital display 209 which will thus display instantaneous flow rate in kilograms per minute, for example.

15 An integrate function 210 operates on successive instantaneous flow rate samples from memory 208 to determine total mass flow or "yield" over the measurement period. The output of the integration operation is stored in memory 211 for outputting to display 209 whenever required.

In the two forms of meter described two different transducers have been used,
20 namely a force transducer and a displacement transducer. Other transducer types could also be used. It will be appreciated that the meters described are subject to turbulent variable flow of a fluid having variable density. With such a dynamic system the electrical output of the transducers requires signal conditioning to remove noise and the like. To assist in signal conditioning sensors could be used to measure the
25 presence of fluid within chamber 102 at different heights within that chamber. Known sensors such as infrared detectors or conductivity detectors could be used to provide further data to assist in signal discrimination.

Although the two forms of meter described have been described with reference to the measurement of flow rate and total mass flow of milk, it should be understood
30 that the meter of the present invention is useful for measuring flow rate and total mass flow of other fluids, particularly some which are difficult to measure using conventional techniques. Other liquids having entrained gases may be metered as may

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substances having fluid-like flow characteristics. An example of the latter is particulate material such as cereal grains. The description of the working fluid as "milk" and the term "milk meter" have been used with reference to the two embodiments described simply for the purposes of simplification and clarity.

5 Thus it can be seen that, the invention provides a means for measuring flow rate and/or total mass flow which has the advantage that the flow rate measured or total mass flow measured for a homogeneous fluid is substantially independent of the density of the fluid passing through the measuring cell. Thus changes in density do not affect the reading. It will also be apparent that a weight or mass measurement
10 can be obtained without storing or collection of the fluid.

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CLAIMS

1. Apparatus for measuring flow rate of a fluid comprising, a chamber, an inlet to said chamber, an outlet from said chamber, means for determining the mass of fluid in the chamber wherein the shape of said chamber and/or the shape of at least part
5 of the fluid flow path through the chamber is such that the flow rate of a selected fluid through said chamber is in a substantially linear relationship to the mass measured by said means.
2. Apparatus according to claim 1 wherein said mass determining means is a weighing system upon which said chamber is supported.
- 10 3. Apparatus according to either of claims 1 or 2 wherein said chamber and said weighing system are contained within an outer housing, said weighing system being fixed to said outer housing.
4. Apparatus according to any one of claims 1 to 3 wherein said chamber is substantially "egg-shaped".
- 15 5. Apparatus according to any one of claims 1 to 4 wherein said outlet from said main chamber comprises a conduit extending upwardly from the base of said main chamber and a longitudinal slot in the wall of said conduit through which fluid in the chamber may flow.
6. Apparatus according to claim 5 wherein said slot is substantially rectangular.
- 20 7. Apparatus according to either of claims 5 or 6 wherein a baffle plate having dimensions greater than those of said slot is provided in said chamber in front of but spaced apart from said slot to thereby cause the fluid to flow around the edges of the baffle before passing through said slot.

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8. Apparatus according to claim 7 wherein an inlet chamber having a fluid inlet thereto is incorporated in said housing above said chamber and adapted to discharge into said chamber.
9. Apparatus according to claim 8 wherein said inlet chamber is circular in
5 horizontal cross section and said fluid inlet is positioned to cause rotational or cyclonic movement of said fluid within said inlet chamber.
10. Apparatus according to either of claims 8 or 9 wherein a distribution plate is provided between said inlet chamber and said chamber, said distribution plate oriented horizontally in use and having a plurality of apertures or slots therein
10 through which said fluid passes into said main chamber.
11. Apparatus according to claim 10 wherein said distribution plate has a single aperture through which fluid passes into said main chamber.
12. Apparatus according to either of claims 10 or 11 wherein said distribution plate has a substantially annular groove therein, said apertures being provided in the base
15 of said groove.
13. Apparatus according to any one of claims 1 to 3 wherein said chamber is rectangular in transverse cross section with an indentation in one long side, wherein said outlet is a slot in said indentation has two sides which are parallel and the other two sides taper inwardly towards the bottom of the chamber.
- 20 14. Apparatus according to claim 13 wherein said chamber has two top opening inlets each disposed adjacent a tapered side.
15. Apparatus according to claim 14 wherein two baffles are located within said chamber oriented parallel to said slot and each are located in a fluid flow path from a respective inlet to said outlet slot.

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16. Apparatus according to any one of claims 2 to 15 wherein said weighing system is a load cell arranged to produce a voltage directly proportional to the weight exacted on the cell.
17. Apparatus according to any one of claims 2 to 15 wherein said weighing system
5 is spring means and a displacement transducer coupled to said chamber arranged to produce a voltage directly proportional to displacement.
18. Apparatus for measuring total mass flow of a fluid comprising apparatus for measuring flow rate according to any one of claims 1 to 17 and summation means to determine total mass flow by integrating a plurality of measurements of said flow rate
10 with respect to time.
19. A method of measuring flow rate of a fluid comprising the steps of passing fluid through a chamber, and determining the mass of fluid in said chamber, said chamber being shaped and/or at least part of the fluid flow path through the chamber being shaped such that the flow rate of a selected fluid is in a substantially linear
15 relationship to the mass of fluid within said chamber.
20. A method of measuring total mass flow of a fluid comprising measuring flow rate according to the method of claim 19 and integrating a plurality of measurements of said flow rate with respect to time to determine a total mass flow of fluid passed through said chamber.

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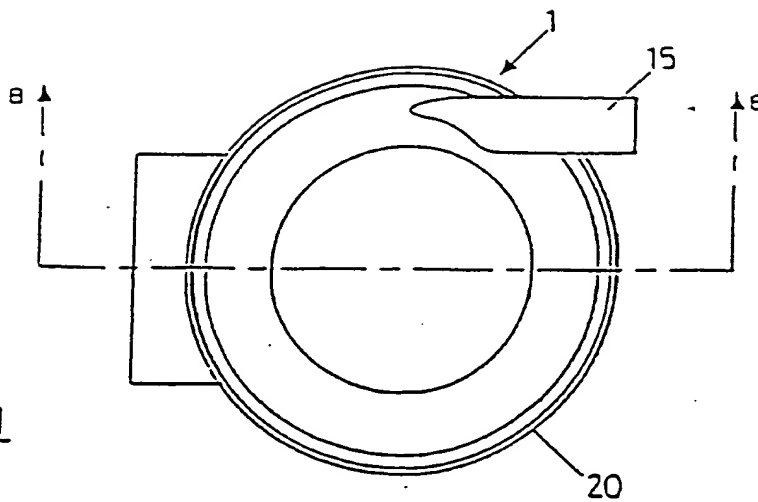


FIG 1

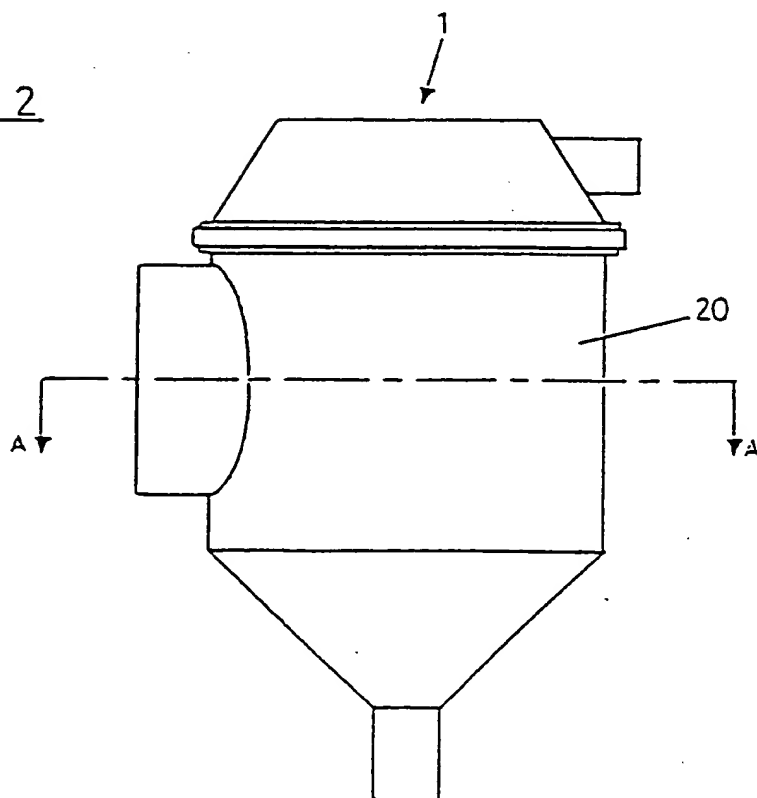


FIG 2

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FIG 3

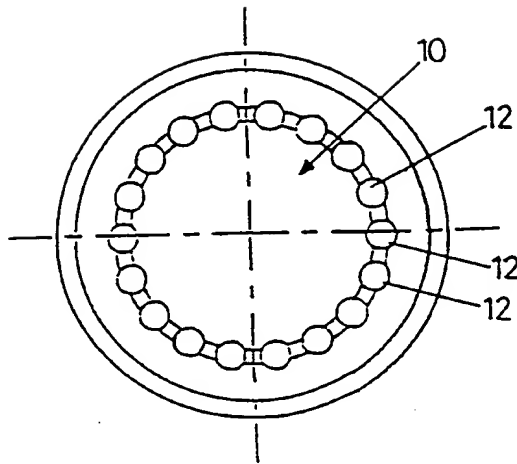
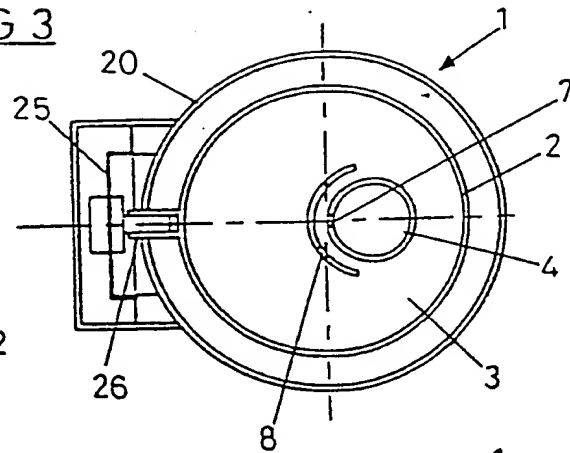
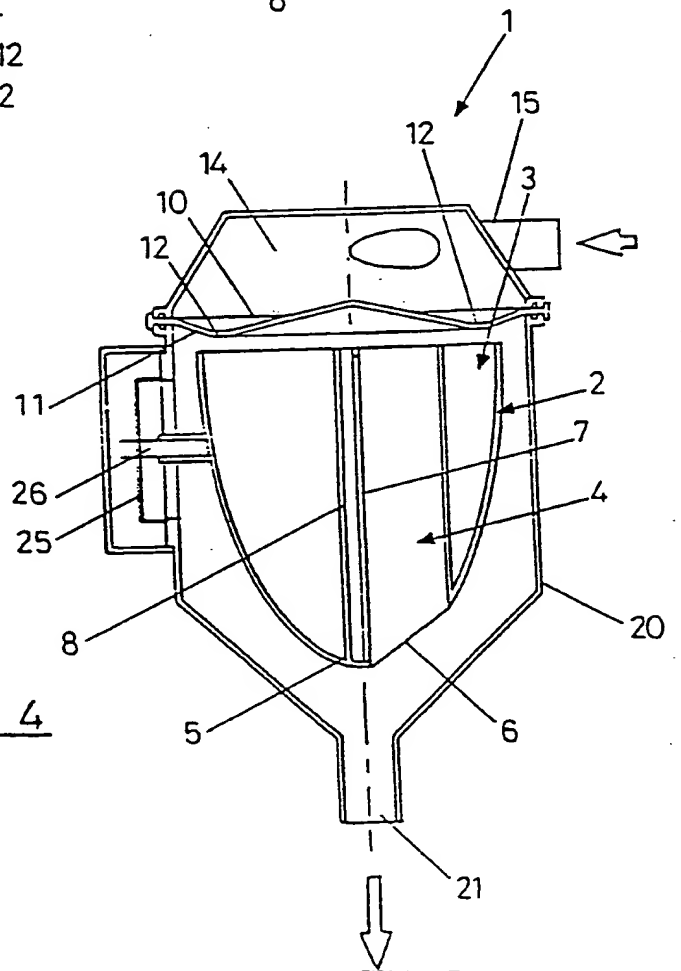


FIG 5

FIG 4



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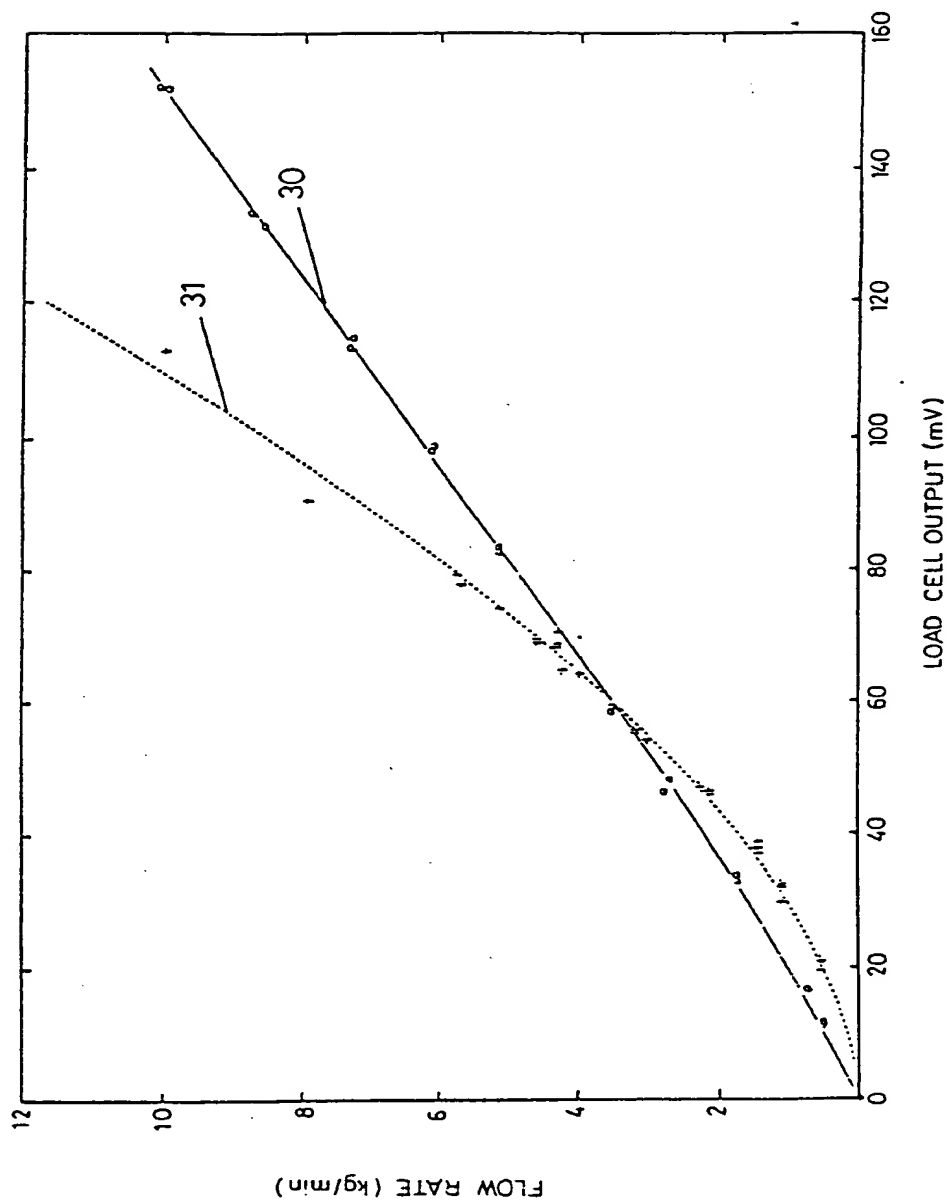


FIG 6

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FIG 7

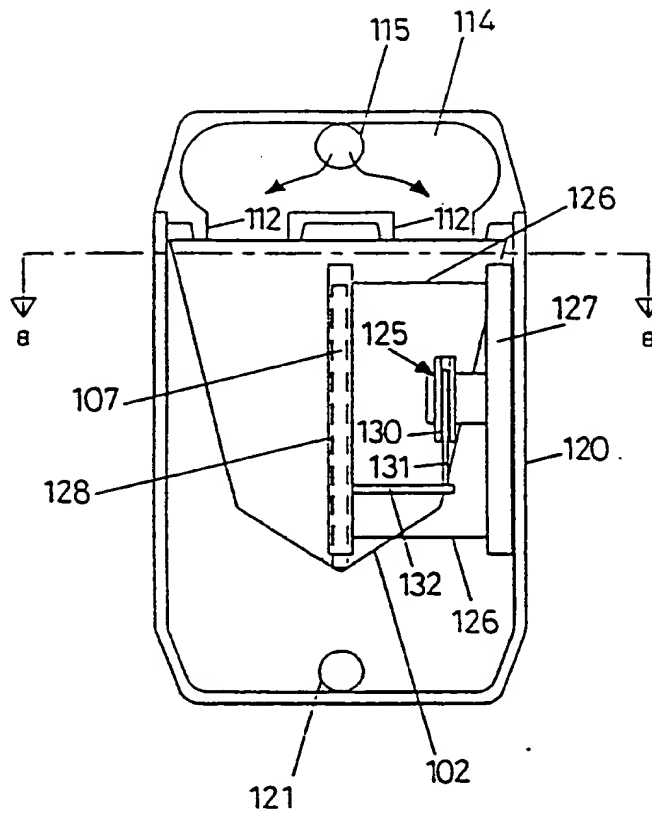


FIG 8

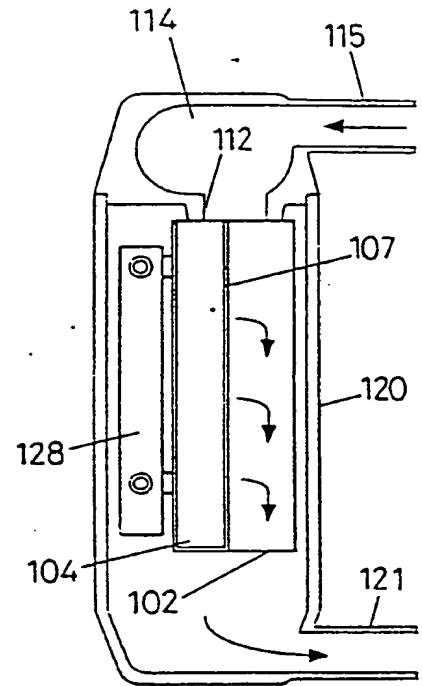
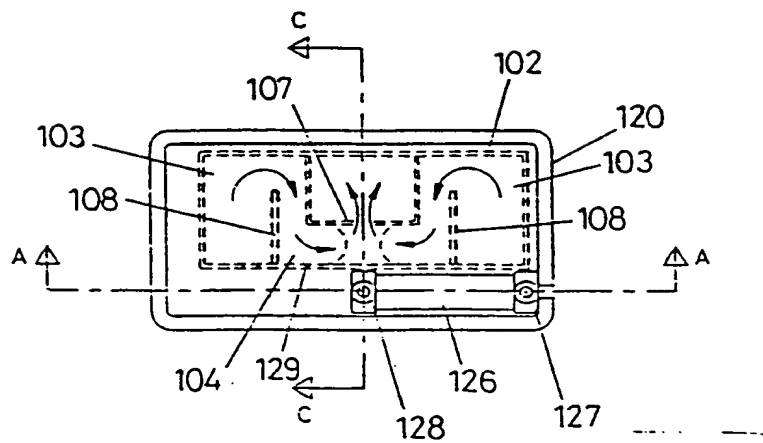
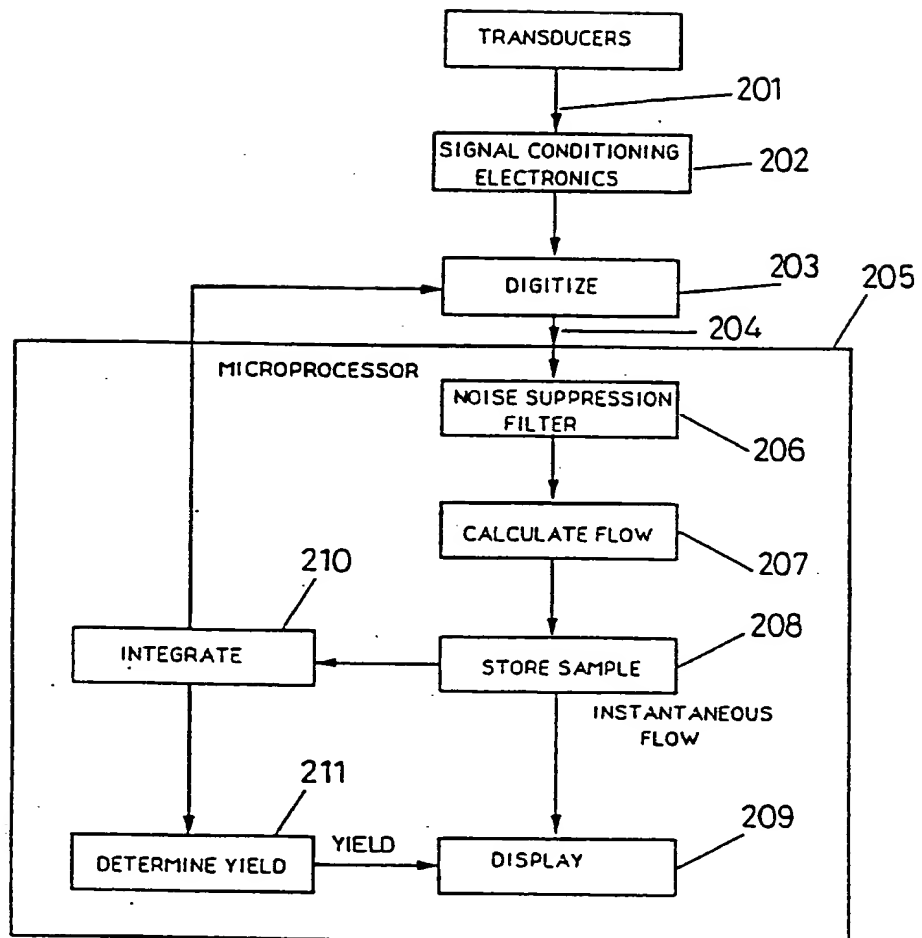


FIG 9



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FIG 10

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INTERNATIONAL SEARCH REPORT

PCT/NZ 93/00077

International Application No

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ⁶		
According to International Patent Classification (IPC) or to both National Classification and IPC		
Int.Cl. 5 G01G17/04; A01J7/00		
II. FIELDS SEARCHED		
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Classification System	Classification Symbols	
Int.Cl. 5	G01G ; A01J	
Documentation Searched other than Minimum Documentation to the extent that such Documents are Included in the Fields Searched ⁸		
III. DOCUMENTS CONSIDERED TO BE RELEVANT⁹		
Category *	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
A	DE,A,3 729 439 (WURSCHUM GMBH) 16 March 1989 see abstract see column 4, line 47 - column 5, line 7; figure 1	1
A	DE,A,3 404 581 (MIELE & CIE GMBH & CO.) 14 August 1985 see page 5, last paragraph - page 6, paragraph 2; figure 1	1
A	EP,A,0 228 100 (KUMMER ELECTRONICS B.V.) 8 July 1987 see page 5, line 1 - line 11; figure 1	1
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IV. CERTIFICATION		
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III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
A	EP,A,0 315 201 (BIOMELTECHNIK HOEFELMAYR & CO.) 10 May 1989 cited in the application see claim 1 -----	1

ANNEX TO THE INTERNATIONAL SEARCH REPORT
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NZ 9300077
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE-A-3729439	16-03-89	None	
DE-A-3404581	14-08-85	None	
EP-A-0228100	08-07-87	NL-A- 8502938 US-A- 4745880	18-05-87 24-05-88
EP-A-0315201	10-05-89	DE-A- 3737607 AU-B- 606762 AU-A- 2453588 JP-A- 2138829 US-A- 5035139 US-A- 5094112	24-05-89 14-02-91 11-05-89 28-05-90 30-07-91 10-03-92

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